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2.	Patent application number *(The Patent Office will fill in this part)*	**9903783.0**
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)* Patents ADP number *(if you know it)* If the applicant is a corporate body, give the country/state of its incorporation	THE UNIVERSITY COURT OF THE UNIVERSITY OF EDINBURGH OLD COLLEGE, SOUTH BRIDGE, EDINBURGH EH8 9YL 7996 78001 UNITED KINGDOM
4.	Title of the invention	VEHICLE DETECTOR AND CLASSIFIER
5.	Name of your agent *(if you have one)* "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)* Patents ADP number *(if you know it)*	J.Y. & G.W. JOHNSON KINGSBOURNE HOUSE, 229-231 HIGH HOLBORN, LONDON WC1V 7DP 976001
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7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application / Date of filing *(day / month / year)*
8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	yes

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	7
Claim(s)	
Abstract	
Drawing(s)	4

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Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature JYL GW Johnson Date 18.2.99.

12. Name and daytime telephone number of person to contact in the United Kingdom

Mr William Hanson
0171 405 0356

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VEHICLE DETECTOR AND CLASSIFIER

The present invention relates to a vehicle detector and classifier.

There is a growing world-wide market for systems for detecting and classifying road vehicles. Road tolling, road pricing, and traffic monitoring and control are becoming increasingly important. Such systems are also likely to be of use in the automated or intelligent highways of the future. Accurate, low cost, low maintenance sensors are required which can not only detect but classify vehicles for automatic tolling and priority lane enforcement. The invention is also applicable to aircraft ground control and military vehicle classification.

One form of vehicle detector in common use comprises one or two large loops of electrically conductive material which are arranged on or in a road, substantially in the plane of the road surface. Vehicles are detected by the reduction in the inductance of the loop caused by the metallic vehicle body passing thereover.

Whilst detectors of this kind can be used to classify vehicles according to their length, they do not detect the axles or wheels of the vehicle and hence classification according to the number, type and position of axles or wheels is not possible. Such classification is, however, the accepted and sensible way to classify vehicle types.

Axle classification can be achieved by using a pneumatic tube or piezoelectric sensor in addition to the inductive loop. However, this adds to the cost, is impractical on unsurfaced roads, has a limited life span and cannot detect individual wheel configurations.

It is therefore highly desirable to provide an inductive loop vehicle detector which can detect vehicle wheels.

EP-A-0,649,553 describes a vehicle detector comprising at least one and up to eight inductive loops, having a width (extending in the direction of travel) only substantially equal to the bearing surface on the ground of the vehicle wheel (i.e. about 0.3 m for heavy goods vehicles or 0.15 m for light vehicles). The or each loop is arranged substantially in the plane of the road surface. This arrangement is able to detect vehicle wheels although the influences of the metallic masses of the body and of the tyres of the vehicle on such small loops are opposed.

The reason given in EP-A-0,649,553 for these opposite influences is that the loop or loops constitute a first electrical circuit, and the metallic mass of the vehicle causes a variation in the magnetic field produced by the first circuit, which in turn causes a variation in the flux linking a second circuit formed by the metallic masses in the wheel and, more particularly, by the torus formed by the wheel rim and the metallic tyre reinforcements, thus inducing a current in the second circuit.

We believe that such reasoning is erroneous since it would cause a change in the inductance of the loop opposite to the results actually described and shown in EP-A-0,649,553. In fact, whilst the large conducting area of a vehicle body causes a decrease in the loop inductance due to eddy currents, the vehicle tyre contains ferrous metal but in the form of steel bands or webbing, not in the form of a large conducting sheet. The vehicle tyre thus has a high magnetic permeability, but a relatively low electrical conductivity, and causes a decrease in the loop inductance.

It is an aim of the present invention to provide a vehicle detector which is able to detect vehicle wheels, tyres and hence axles more accurately than has been possible hitherto.

Accordingly, the present invention comprises a vehicle detector and classifier comprising at least one electrically conductive loop arranged in a road surface, characterised in that the or each loop is arranged substantially in a plane perpendicular to the road surface.

Said plane may extend parallel to the axis of the road, i.e. in the direction of travel, but preferably it extends across the road. This means that a plurality of loops may be arranged in a line in a single transverse slot cut into the road surface.

The or each loop may comprise a plurality of turns. The signal processing circuitry used to sample the inductance of the loop and operate on the samples may comprise one of a number of conventional arrangements currently used in inductive loop vehicle detectors. In this regard, some of the active electronic components, such as the oscillator, can be located in the slot adjacent to the or each loop so as to reduce interference between the loops and reduce crosstalk between the circuits. Any such components are preferably mounted on very small hybrid or thick-film circuits at regular intervals. The loop, or all of the loops, and optionally the locally mounted components, are preferably encapsulated in a semi-rigid enclosure which is strong yet flexible so as to be able to withstand the forces exerted by heavy vehicles passing thereover.

The or each loop is preferably substantially rectangular and may, for example, have a length of between 5 and 15 cm and a width (i.e. a depth) of between 1 and 3 cm. In a particular embodiment, a plurality of loops each measure approximately 10 cm x 2 cm.

In a preferred embodiment of the invention, the detector also includes an inductive loop arranged substantially in the plane of the road surface. This conventional loop is used to detect vehicle bodies whilst the or each vertically-orientated

loop is used to detect wheels. Preferably, the detector includes means for superposing results obtained from the conventional and vertically-orientated loops and means for displaying the superposed results. Thus, a profile showing both the chassis and the axles or wheels of a vehicle can be viewed.

The present invention will now be described in more detail, by way of example only, with reference to the accompanying drawings, in which:-

Figure 1 is a schematic vertical elevation of a vehicle detector according to one embodiment of the invention;

Figure 2 is a schematic transverse section of the detector shown in Figure 1;

Figures 3a and 3b schematically show an alternative embodiment of detector at two different instants for double and single tyres respectively;

Figures 4a and 4b are plots of results obtained from the detector as shown in Figures 3a and 3b respectively;

Figure 5 is a schematic bottom view of a model vehicle;

Figures 6a and 6b are surface and contour plots respectively obtained when the vehicle shown in Figure 5 passes over a detector according to the invention; and

Figure 7 is a plot of superposed results obtained from a combined detector according to another alternative embodiment.

Figures 1 and 2 show a detector comprising a linear array of inductive loops 1, the number of loops being as required to cover the width of carriageway to be monitored. For example about 20 loops can cover a width of 3 m. In this

example, each loop measures 10 cm x 2 cm. The array of loops is arranged in a narrow slot 2 extending transversely across a road surface. Each loop 1 comprises a plurality (e.g. 20 to 30) turns of wire. Each loop 1 is both energised and monitored by an adjacent electronic circuit 3, comprising, inter alia, an oscillator and circuitry to convert the oscillation frequency into a proportional signal voltage (not shown in detail). The circuits 3 are very small hybrid or thick-film circuits. The entire array of loops 1 and circuits 3 is housed within a semi-rigid enclosure 4 for protection against the mechanical forces exerted by vehicles passing over the detector.

The signal processing circuitry used to operate inductive loop vehicle detectors is well documented and no special adaptations are required for operating the detector of the present invention. It is not therefore necessary to set out the details of the circuitry herein. An example of such circuitry is described in EP-A-0,649,553, but other known arrangements are equally suitable for use with the present invention.

Figures 3a and 3b schematically show an embodiment of the invention comprising two 10 cm x 2 cm loops 5a, 5b which was built and tested. The two-loop array was mounted in a narrow trench and a large van was driven thereover. Figure 3a shows a front wheel 6 of the van passing over the loop 5a whilst Figure 3b shows doubled rear wheels 7 passing over both loops 5a, 5b. The results are plotted in Figures 4a and 4b, with the solid line showing the ADC (analogue-to-digital converter) reading for the loop 5a and the broken line showing the ADC reading for the loop 5b. Figure 4a shows the recording corresponding to Figure 3a and Figure 4b the recording of Figure 3b. The outputs are very distinct, giving a clear indication of the presence of the wheel and it is possible to see the difference between the front and rear wheels. The presence of the large conducting area of the underside of the

van has not destroyed the data relating to the wheels, as would happen with a conventional loop.

Figure 5 shows the dimensions in mm of a scale model vehicle used to test an experimental embodiment of the invention. The model vehicle had wheels exhibiting the same properties as real vehicle wheels. Figures 6a and 6b show the results obtained as a 3D surface plot and a contour plot respectively.

A practical embodiment of the invention comprises at least one vertically-orientated inductive loop as described above as well as a conventional large flat loop which may be up to 1.5 to 2.5 m long in the direction of travel. Such a combined detector has been constructed. The results from the vertical and flat loops were superposed, the results from the vertical loop firstly being inverted since, as explained above, tyres cause a increase in the loop inductance whilst the vehicle body causes a decrease. The superposed results are shown in Figure 7 as an illustration of what can be achieved. The profile indicates both the chassis and the axles of the vehicle. This could also be displayed as a 3D plot, similar to Figure 6a, if an array of vertically oriented loops is used such as that shown in Figure 1.

When the detector comprises a linear array of miniature loops it is possible to detect the track width and even the size and configuration of the vehicle wheels. The lateral position of the vehicle on the road can be detected and thus a vehicle straddling two lanes of a road is easily identified and is not mistaken for two vehicles. Metal-tracked vehicles can also be distinguished since the tracks will cause a decrease in the loop inductance, whereas tyred vehicles cause an increase in inductance.

The inductive signature of the loop(s) of the invention has a better resolution than that of conventional loops due to the size and orientation of the loop of the invention.

This helps to resolve tailgating and nose-to-tail congestion problems encountered by conventional loops. This range of data is not readily available from video processing, even in good weather and lighting conditions.

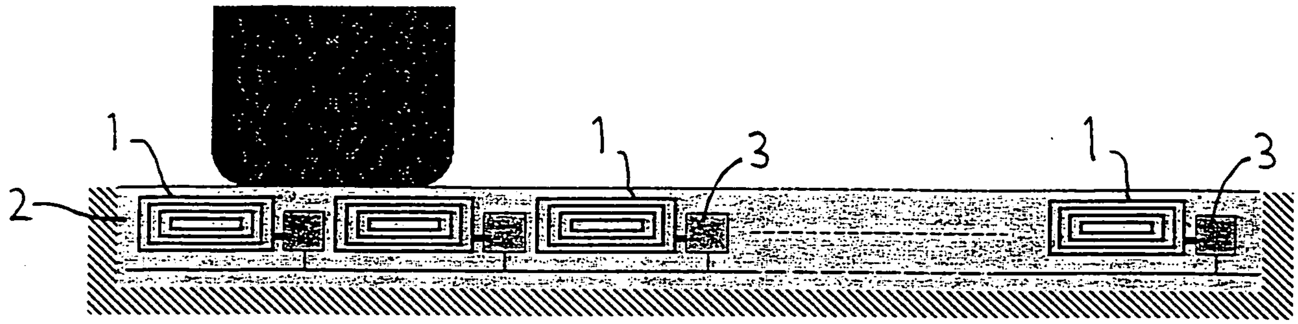

Fig. 1

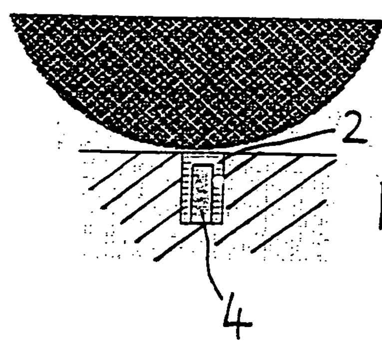

Fig. 2

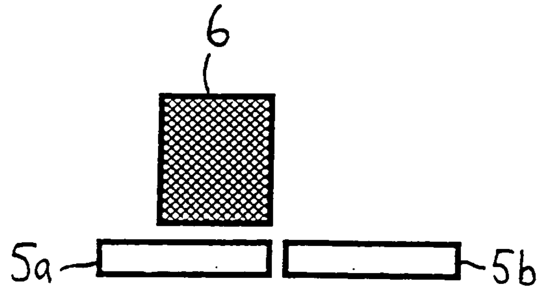

Fig. 3a

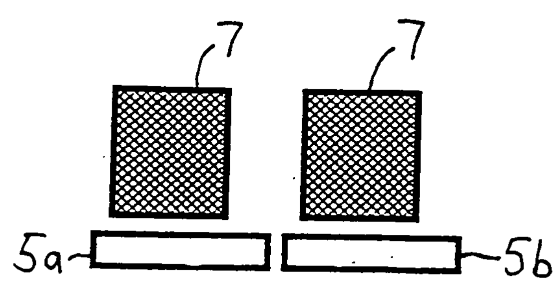

Fig. 3b

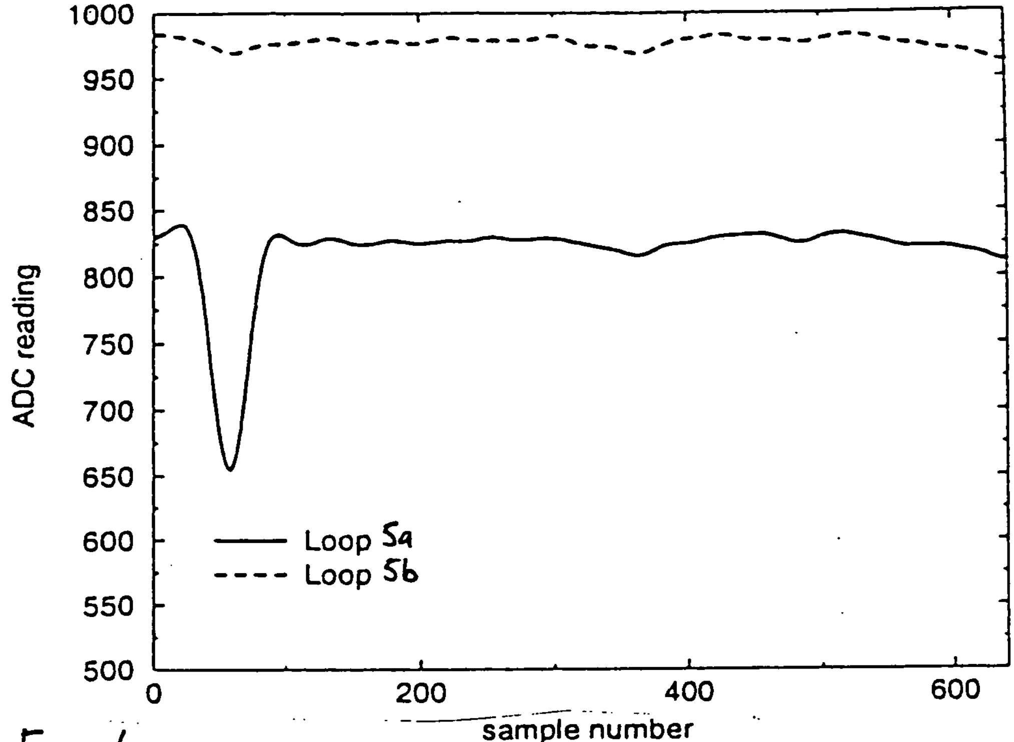
1000
950
900
850
800
750
700
650
600
550
500
ADC reading
Loop 5a
Loop 5b
0
200
400
600
sample number

Fig. 4a

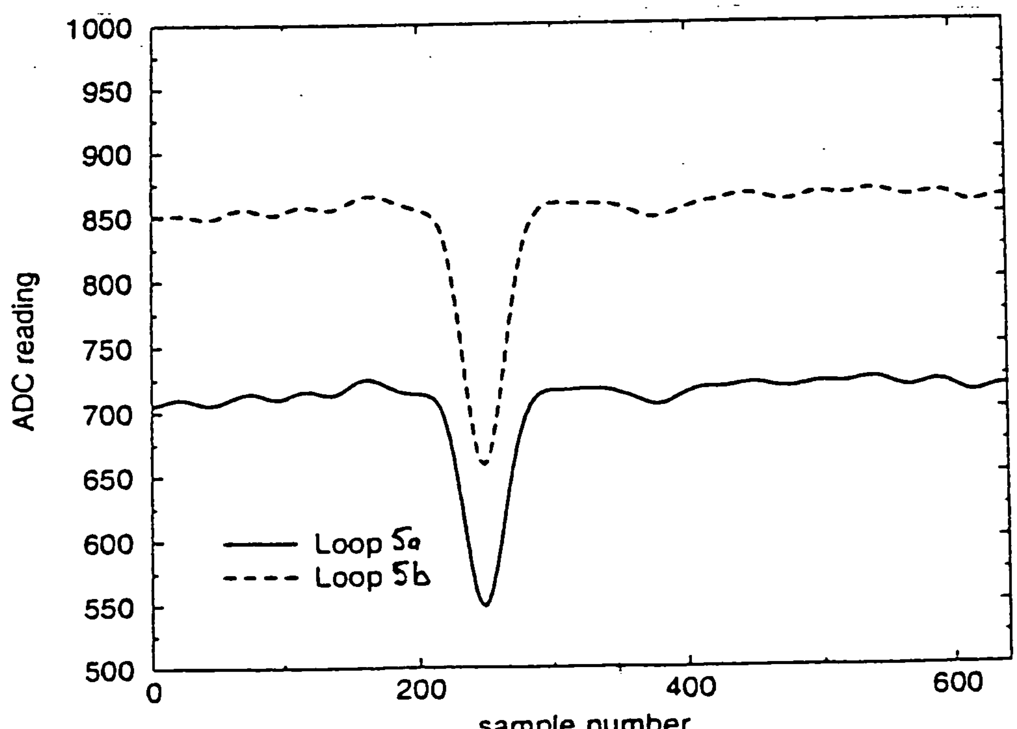
1000
950
900
850
800
750
700
650
600
550
500
ADC reading
Loop 5a
Loop 5b
0
200
400
600
sample number

Fig. 4b

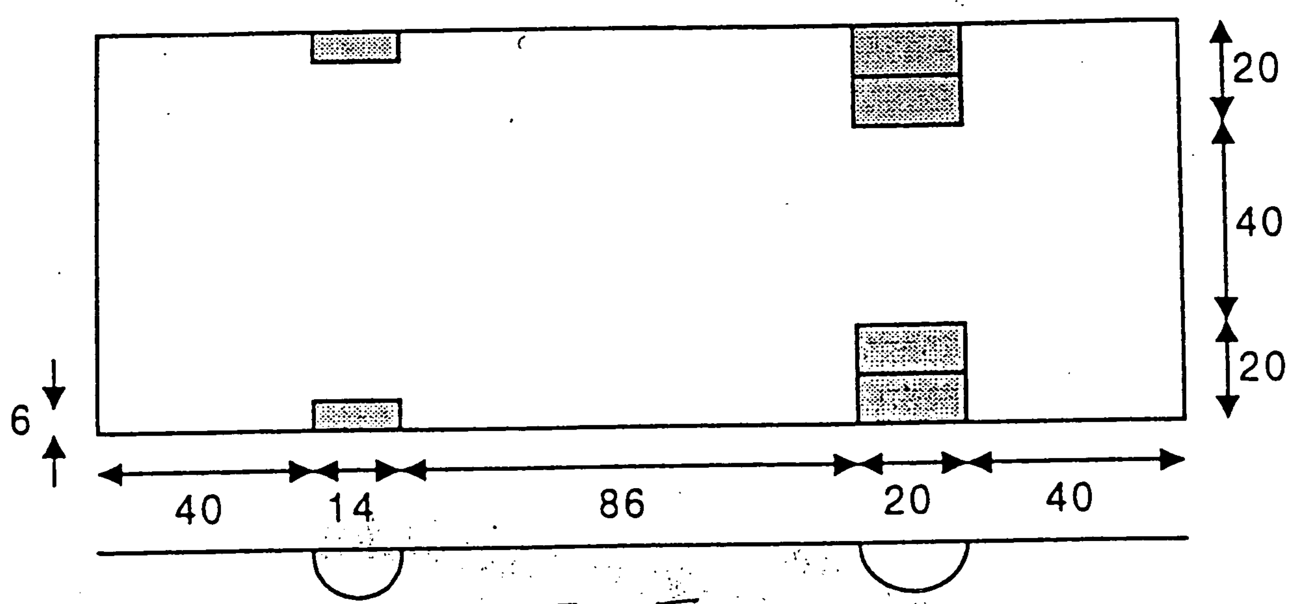
20
40
20
6
40
14
86
20
40
Front
Rear

Fig. 5

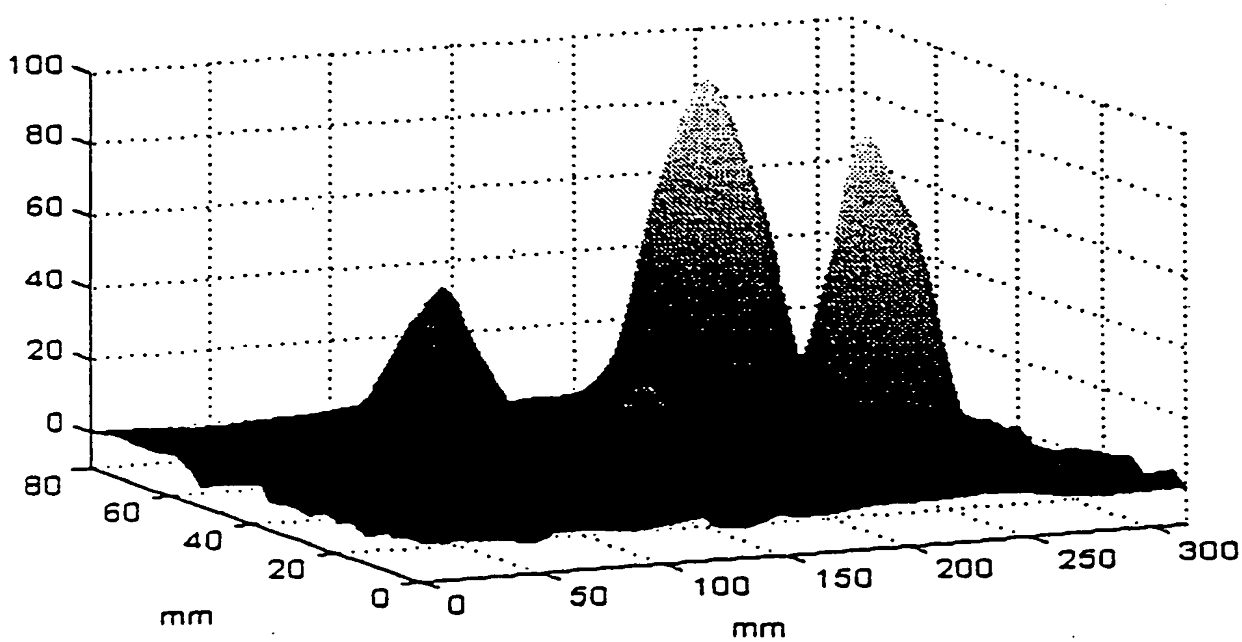
100
80
60
40
20
0
80
60
40
20
0
mm
0
50
100
150
200
250
300
mm

Fig. 6a

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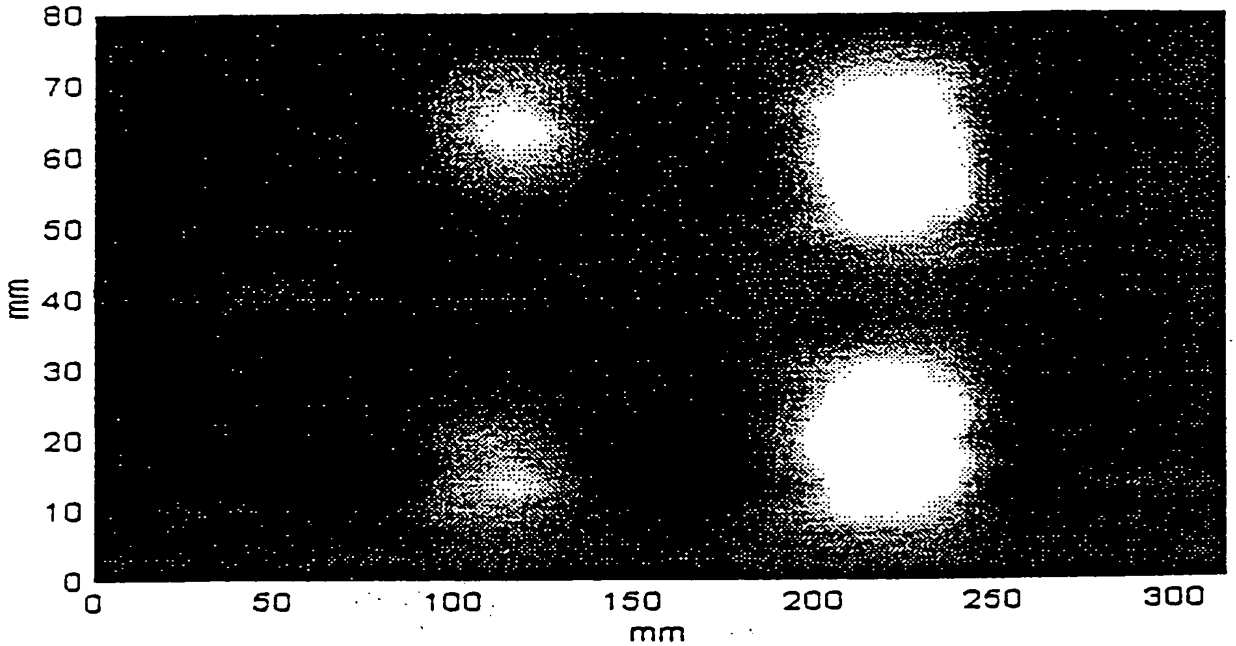
80
70
60
50
mm 40
30
20
10
0
0
50
100
150
200
250
300
mm

Fig. 6b

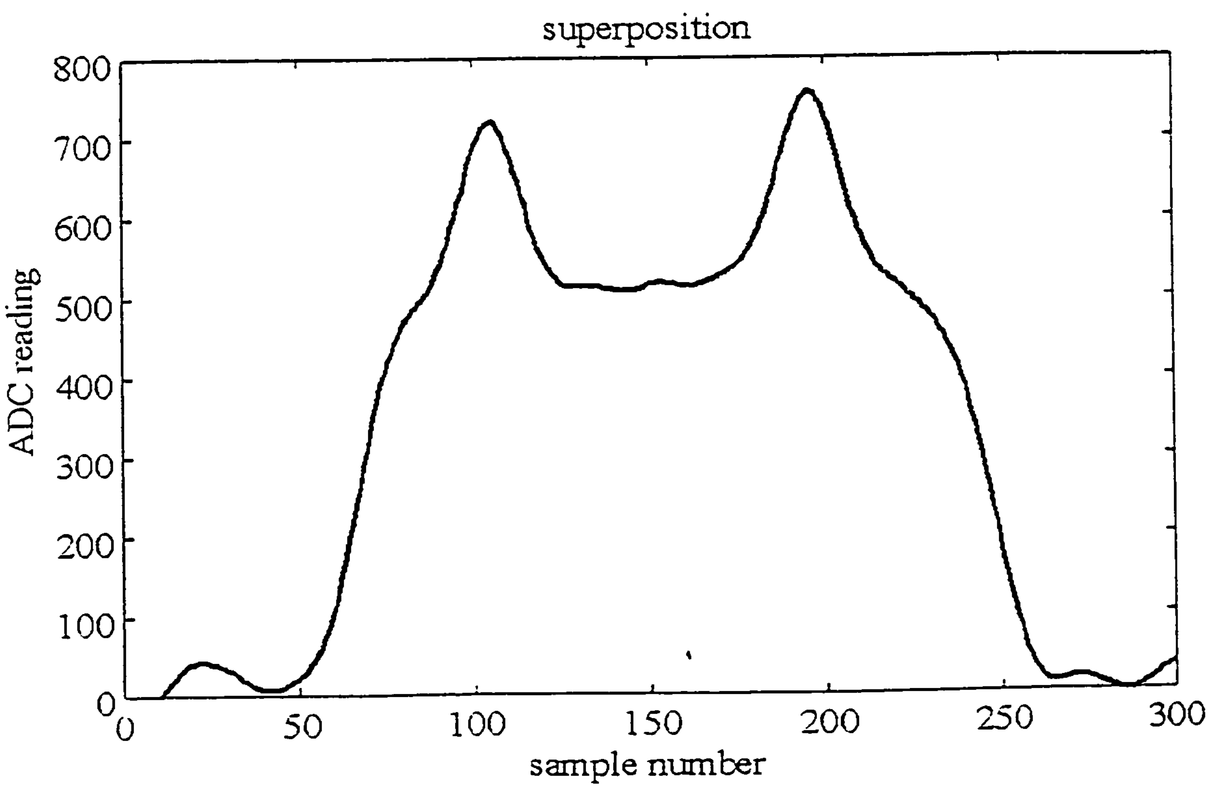
superposition
800
700
600
500
400
300
200
100
0
ADC reading
0
50
100
150
200
250
300
sample number

Fig. 7

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